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Speed thrills but kills: A case study on seasonal variation in roadkill mortality on National highway 715 (new) in Kaziranga-Karbi Anglong Landscape, Assam, India

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Abstract

Animal-vehicle collision on the roads is a major cause of mortality of a wide range of animal taxa both within and around protected areas. This study has been conducted in the National Highway 715 (new) covering a continuous stretch of 64 km that passes through Kaziranga National Park (KNP) of Assam (India). The area falls between the boundary of KNP on its north and North Karbi Anglong Wildlife sanctuary on the south. The survey concentrated on the mortality study of four groups of vertebrates viz., amphibians, reptiles, birds, and mammals resulting from collisions with vehicles from October 2016 through September, 2017. A total of 6036 individual roadkills were registered, belonging to 53 species, 23 other taxa and 30 families of vertebrates, with herpetofauna being the most affected group followed by birds and mammals. The study evaluated seasonal variation in the overall roadkill pattern with highest mortality in the monsoon season 38.27% (n = 2310) and with peak casualties starting with the onset of rainfall (February and March) and during monsoons (July and August). The amphibian mortality was also found to be highest during the monsoon with 43.28% (n = 1575) of kills, as compared to the other three groups. NH-715 (new), therefore serves as a challenging passage for the animals, forming a major barrier for the faunal component of the Kaziranga-Karbi Anglong landscape. This study thus tried to reflect the often overlooked issue of roads and highways in terms of direct mortality of animals due to traffic and thereby can be helpful in understanding the seriousness of the situation and identifying prospective measures to be taken for sustainable coexistence of both animals and human.

Keywords
Herpetofauna, Kaziranga National Park, mortality, National Highway, road ecology, vehicular collision

Introduction

India has the second largest road system in the world according to the National Highway Authority of India (NHAI) covering over 5.89 million kilometres with all signs pointing to an explosion of expansion in the upcoming years (Indian Road Industry Report 2020). The state of Assam has a total road length of 47,936 km including 3908.5 km of National Highways, 3134.36 km of State Highways, 413.03 km of major district roads and 37 030 km of rural roads (India Brand Equity Foundation 2019). In India, the total length of roads and the number of automobiles has increased tremendously. The total extent of roads in India has increased more than 11 times during the past six decades from 1951 to 2015 (from 3.99–46.71 lakh kilometre), which was 4.2% in 1950's (ROADS-Statistical Year Book 2018). The number of registered motor vehicles has also been growing at a compound annual growth rate (CAGR) of 10.16% per year over the last five years. Considering this vast network of roads, it is crucial to assess the magnitude of wildlife mortality due to road traffic (Glista et al. 2008).

Roadways are obviously integral to commuting and transportation, but are certainly known to pose some detrimental effects on the flora and fauna surrounding them (Mazumdar and Gogoi 2010). They may affect animal populations in different ways. The most prominent effect of such linear structure is mortality through vehicular collisions (Das et al. 2007; Grilo et al. 2018; Jeganathan et al. 2018). Other more complex consequences identified are habitat modification and fragmentation (Carr and Fahrig 2001), leading to population isolation, changes in animal distribution and movement patterns (Desai and Baskaran 1998), increased inbreeding, decrease in population size and high possibilities of local extinction (Quinn and Hasting 1987). Another corollary effect of road is the volume of space they occupy (Trombulak and Frissell 2000), contamination of roadside habitats due to automobile exhaustions (Beeby and Richmond 1987) and increased avoidance behaviour, thus acting as a barrier to gene flow (Mader 1984). The effect of such infrastructures is felt by mammals (Baskaran and Boominathan 2010), birds (Robertson 1930), reptiles (Das et al. 2007), amphibians (Seshadri et al. 2009) and macro invertebrate fauna (Haskell 2000) as well. Thus, road fragments the habitats, and with the growing demand for more networks, animals are increasingly forced to cross roads to perform their routine necessities and are often killed by vehicles (Hourdequin 2000).

Among the various threats posed to wildlife, collisions with vehicles are becoming a major concern for many species (Bager and Rosa 2011). Road attributes like width, length and condition of the pavement, directly amplify the rate of vehicular collisions. Setting up roads and measures without proper structural designs, leads to an increased rate of vehicular collisions for animals (Oxley et al. 1974). Road

density and their constructional works can harm and alter biodiversity at local, regional and landscape scales, the effect of which can sometimes remain unnoticed for decades (Findlay and Houlahan 1997). The International Union for Conservation of Nature (IUCN) also considers roads and railways in their list of threats for various wild animals. Mortality due to vehicular collision for any sustaining population may not exhibit the need of immediate conservation concerns, but it is presumed that small, isolated, declining, threatened populations and species are also affected by road mortality (Mumme et al. 2000). Species-specific behaviour in response to the road environment also guides the risk of vehicular collisions (Erritzoe et al. 2003). Many species use the road for daily activities like foraging, nesting, predation, scavenging, shelter, which can increase their vulnerability to road mortality (Fulton et al. 2008). Road habitats may also act as a habitat sink or ecological trap for birds and small mammals (Mumme et al. 2000).

Factors like roadkill rates, traffic traits and landscape attributes are effective in determining the spatial location of roadkills (Ramp et al 2005), but their temporal distribution for predicting seasonal patterns have been addressed less often. Explanations for seasonal variation in roadkill have been correlated to the breeding and foraging behaviour of the species (Erritzoe et al. 2003). The temporal roadkill patterns of small mammals, birds, and lizards are also linked to their phenology (D'Amico et al. 2015). In Amphibia, seasonal peaks in population sizes (Rosa and Bager 2012) and migration (Langen et al. 2009) have also been related to temporal roadkill patterns. Environmental variations and seasonal life-history traits (D'Amico et al. 2015; McCardle and Fontenot 2016) can also cause temporal or seasonal roadkill peaks.

Our goal in this study was to evaluate the magnitude of mortality due to collisions with vehicles, of vertebrate fauna, specifically amphibians, reptiles, birds, and mammals in the highway stretch that passes through Kaziranga-Karbi Angling landscape complex in North-Eastern India, from October 2016 to September 2017. We also tried to evaluate the seasonal variation and pattern of roadkill distribution among the vertebrate groups in the study area. Similar studies have been carried out in India, but no detailed study for this high diversity hotspot is known yet (Islam and Saikia 2014).

Methods

Study area

The entire study area landscape includes the Kaziranga National Park (KNP, Latitude 26°30'N to 26°50'N and Longitude 92°05'E to 93°41'E), North Karbi Anglong Wildlife Sanctuary, East Karbi Anglong Wildlife Sanctuary (central coordinates: 26°28'0"N, 93°21'29"E), river Brahmaputra and the National Highway (NH) 715 (new) positioned in between KNP and North Karbi Anglong Wildlife Sanctuary, all covering the districts of Golaghat, Nagaon, Sonitpur, and Karbi Anglong.

The studied road site is a continuous 64 km stretch of this NH 715 (new), (Latitude: 26°34'–26°46'N, Longitude: 93°08'–93°36'E) which forms the southern boundary of KNP, connecting Bokakhat to Ghorakati and bisecting the landscape into north and south (Figure 1). In the north lie the low-lying floodplains of KNP and in the south lie the elevated Karbi Anglong hills. This highway is also an Asian Highway No. 1 (AH-1) connecting to Myanmar, and a major communication route to eastern parts of Assam. The NH 715 was formerly known as National Highway 37 (NH 37) and upon revision, now starts from its junction with NH-15 near Tezpur connecting Jakhalabandha, Bokakhat, Jorhat, and terminates at its junction with NH-2 near Jhanji in Sibsagar, Assam for a total length of 197 km.

This paved stretch of highway is 7.5 m wide and crosses a wide array of habitats, including tea gardens, human settlements, agricultural fields, grassland, teak plantations, bamboo plantations, wetlands, open fields, swamps and marshy areas and forest covers at Panbari, Haldibari, Kanchanjuri, and Gorakati areas. The animal movement pattern along the highway can be summarised into two seasonal frames, one during the flooding period (April to September) which includes Pre-monsoon and monsoon season (Borthakur 1986), when flooding in Kaziranga (north side) forces the animals to move southwards to higher elevations to escape flooding. The highway lying between KNP and North Karbi Anglong Wildlife Sanctuary, provides a linear raised ground for the animals to take immediate refuge. The other stride occurs during the non-flooding period (October to March) which includes retreating monsoon and winter season (Borthakur 1986), when animals move to neighbouring linking habitats in search of forage and other natural life necessities.

Quantification of roadkill

We conducted 144 systematic road trips from October 2016 to September 2017, for the entire stretch of the highway (64 kms), starting from Bokakhat to Ghorakati and then returning back to the same start point, accounting for approximately 128 kms for every instance. Data collection was carried out by two observers beginning at 07:00 h during winter and at 05:00 h in summer, depending upon visibility, using a motor vehicle at a steady speed of 25–35 kmph, for three days every week. Survey effort was kept constant throughout the year. This intensive sampling design was incorporated to enhance the detection of smaller carcasses, which could rapidly dissipate due to degradation or scavenging (Glista et al. 2008).

Each encountered carcass was identified to the species level, whenever possible, otherwise to genus or family level. Also, the number of individual carcasses and their status were recorded along with geo-location using a Garmin eTrex 10 GPS. The carcass status was defined as Fresh (carcass found in fresh condition or live killed) or Old (dry carcasses or few remains). All the carcasses were grouped by class as mammal, bird, reptile, and amphibian. The animal carcasses encountered were photographed for identification and were removed from the road to avoid double counting. At certain

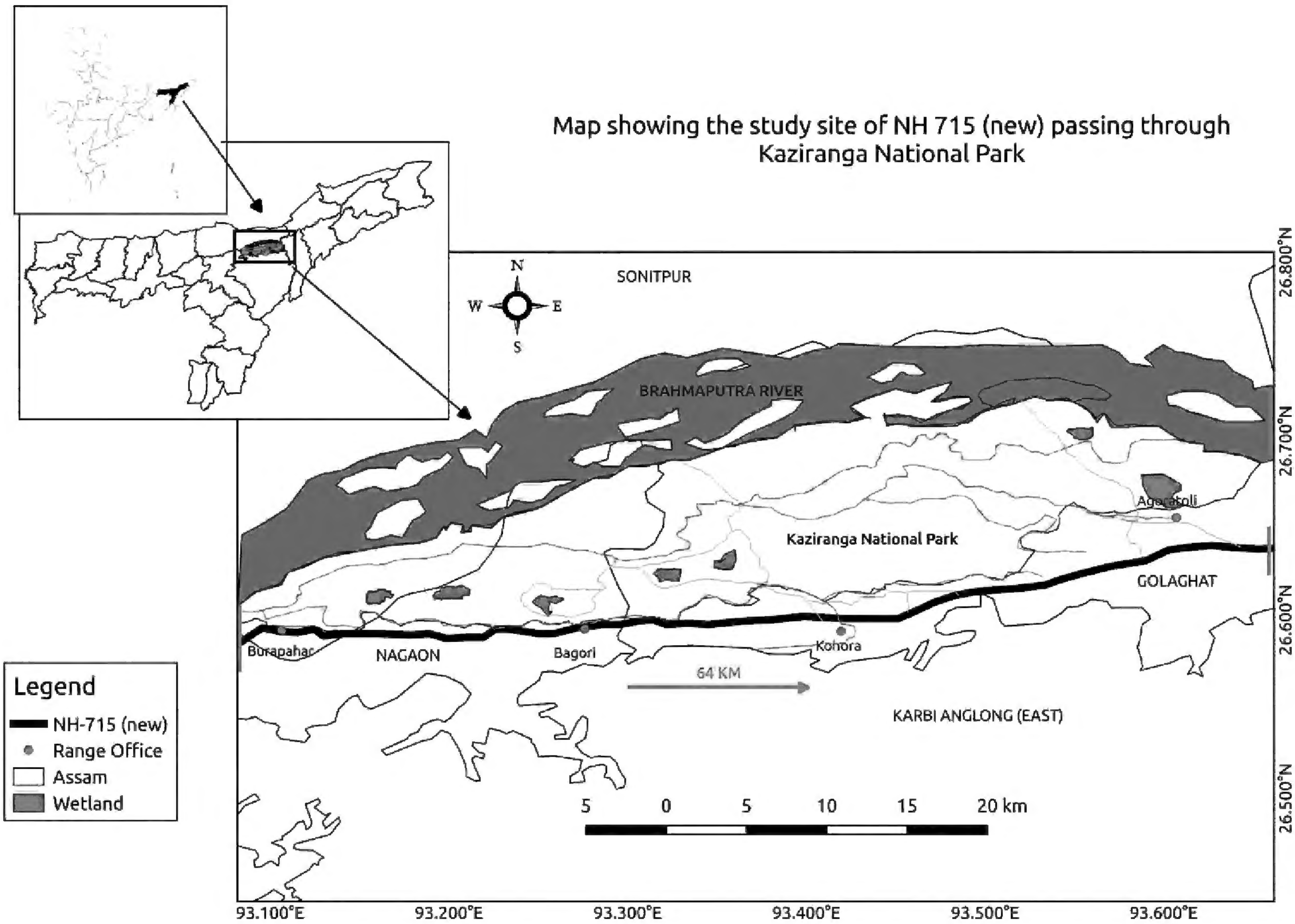

Figure 1. Map showing the study site of NH 715 (new) passing through the KNP.

surveys the amphibian carcasses were so locally abundant that individual counting was not possible. In those situations, an abundance estimate was made at each 10 m-road section. The carcasses were identified using field guides for respective taxa (Dutta 1997; Das 2002; Whitaker and Captain 2004; Grimmett et al. 2011; Menon 2014). Some carcasses found in a severe distorted condition, were grouped as unidentified. Variation in observers can also affect detection rates of dead animals (Kline and Swann 1998).

Animals, specifically reptiles, crossing the road or basking on the road were assisted towards the direction in which they were moving.

Data analysis

We used non-parametric Kruskal-Wallis ANOVA and Mann-Whitney U tests to examine the differences in mean number of roadkill by taxonomic group, month, season, and carcass status. Periods of roadkill occurrences were classified as non-flooding and flooding period. Seasons were defined as winter (December – February), pre-monsoon (March – May), monsoon (June – August) and retreating monsoon (September – November). All the analyses were performed for the total number of roadkills, excluding the unidentified carcasses. All statistical analyses were done using R (R Core Team 2013).

Results

Overall results

We registered altogether 6036 individual roadkills belonging to 53 species (30 families) of four different vertebrate classes during the study period. A total of 121 roadkills (1.92%) remained unidentified because of their bad condition (Table 1). Amphibians were the most affected class, accounting for60.29% of all roadkill (n = 3639) belonging to two families. The reptiles were the second most road-killed class with 21.22% (n = 1281), with eight families. Birds comprised 9.87% of roadkill (n = 596), with 15 families and mammals constituted 8.61% of roadkill (n = 520) with kills in five families (Table 1; Figure 2).

Table 1. List of roadkills recorded in different seasons, at NH-715 (new) from October 2016 to September 2017. PM: Pre-monsoon; M: Monsoon; RM: Retreating monsoon; W: Winter; T: Total number of individuals.

Order	Family	Common name	Scientific name	Roadkill animals				
				PM	M	RM	W	T
			Amphibians					
Anura	Bufonidae	Common Indian Toad	*Duttaphrynus melanostictus*	426	849	50	668	1993
Anura	Dicroglossidae	Indian Bullfrog	*Hoplobatrachus Tigerinus*	60	41	0	31	132
Anura	Dicroglossidae	Fejervarya Spp.	*Fejervarya* Spp.	189	285	6	59	539
Anura	Uncategorised	Toad Spp.	–	156	272	32	206	666
Anura	Uncategorised	Frog Spp.	–	30	22	8	24	84
Unidentified	**Unidentified**	Unidentified	–	63	106	5	51	225
			Reptiles					
Squamata	Typhlopidae	Diard's Worm snake	*Argyrophis diardii*	1	5	0	0	6
Squamata	Typhlopidae	Brahminy Worm Snake	*Rhanphotyphlops brahminus*	2	6	0	0	8
Squamata	Colubridae	Striped Keelback	*Amphiesma stolatum*	33	65	27	17	142
Squamata	Colubridae	Red-necked Keelback	*Rhabdophis subminiatus*	15	13	26	16	70
Squamata	Colubridae	Checkered Keelback	*Xenochrophis piscator*	28	29	25	19	101
Squamata	Colubridae	Common Trinket Snake	*Coelognathus helena Helena*	7	11	0	4	22
Squamata	Colubridae	Copper-headed Trinket snake	*Coelognathus radiatus*	7	8	12	6	33
Squamata	Colubridae	Trinket Snake	*Coelognathus* Spp.	3	4	1	0	8
Squamata	Colubridae	Cat Snake	*Boiga* Spp.	17	18	5	11	51
Squamata	Colubridae	Eastern Cat Snake	*Boiga gokool*	5	9	0	0	14
Squamata	Colubridae	Large-spotted Cat Snake	*Boiga multomaculata*	2	3	0	1	6
Squamata	Colubridae	Eyed Cat Snake	*Boiga siamensis*	1	6	2	6	15
Squamata	Colubridae	Indian Rat Snake	*Ptyas mucosa*	5	8	15	9	37
Squamata	Colubridae	Indo-Chinese Rat Snake	*Ptyas korros*	0	2	0	1	3
Squamata	Colubridae	Ornat Flying Snake	*Chrysopelea ornate*	13	6	8	6	33
Squamata	Colubridae	Painted Bronzeback Tree Snake	*Dendrelaphis pictus*	25	20	21	14	80
Squamata	Colubridae	Bronzeback Tree Snake	*Dendrelaphis* Spp.	7	10	18	16	51
Squamata	Colubridae	Indian Wolf Snake	*Lycodon aulicus*	19	18	7	5	49
Squamata	Colubridae	Yellow-speckled Wolf Snake	*Lycodon jara*	0	6	0	0	6
Squamata	Colubridae	Zaw's Wolf Snake	*Lycodon zawi*	5	3	0	1	9
Squamata	Elapidae	Black Krait	*Bungarus niger*	1	2	0	1	4
Squamata	Elapidae	Banded Krait	*Bungarus fasciatus*	4	8	4	1	17
Squamata	Elapidae	King Cobra	*Ophiophagus hannah*	0	0	0	1	1
Squamata	Elapidae	Krait Spp.	*Bungarus* Spp.	1	1	1	2	5
Squamata	Viperidae	Pit Viper	*Trimeresurus* Spp.	2	7	0	0	9

Order	Family	Common name	Scientific name	Roadkill animals				
				PM	M	RM	W	T
Squamata	Homalopsidae	Common Smooth-scaled Water Snake	*Enhydris enhydris*	2	7	3	3	15
Squamata	Pythonidae	Burmese Python	*Python molurus bivittatus*	9	0	0	0	9
Squamata	Pythonidae	Python Spp.	–	0	1	0	0	1
Squamata	Uncategorised	Snake Spp.	–	36	68	64	53	221
Squamata	Geckoninae	Tokay Gecko	*Gekko gecko*	7	3	0	2	12
Squamata	Geckoninae	Bent-toed Gecko	*Crytodactylus* Spp.	0	1	1	2	4
Squamata	Geckoninae	Lizard Spp.	*Gekko* Spp.	0	2	0	0	2
Squamata	Agamidae	Oriental Garden Lizard	*Calotes versicolor*	61	39	47	66	213
Squamata	Uncategorised	Lizard Spp.	*Calotes* Spp.	0	2	9	7	18
Squamata	Uncategorised	Lizard Spp.	*Unidentified*	0	1	5	5	11
Birds								
Passeriformes	Sturnidae	Common Myna	*Acridotheres tristis*	29	54	32	27	142
Passeriformes	Sturnidae	Asian Pied Starling	*Gracupica contra*	11	12	8	8	39
Passeriformes	Sturnidae	Chestnut Tailed Starling	*Sturnia malabarica*	3	1	1	2	7
Passeriformes	Sturnidae	Jungle Myna	*Acridotheres fuscus*	18	20	8	10	56
Passeriformes	Sturnidae	Common myna/Jungle Myna	*Acridotheres tristis/ Acridotheres fuscus*	5	8	7	9	29
Passeriformes	Cisticolidae	Common Tailorbird	*Orthotomus sutorius*	2	2	0	2	6
Passeriformes	Passeridae	Eurasian Tree Sparrow	*Passer montanus*	6	2	1	1	10
Passeriformes	Passeridae	House Sparrow	*Passer domesticus*	11	5	6	10	32
Passeriformes	Passeridae	Sparrow Spp.	*Passer* Spp.	0	3	0	1	4
Passeriformes	Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	40	32	9	16	97
Passeriformes	Estrildidae	Scaly-breasted Munia	*Lonchura punctulata*	2	1	0	0	3
Passeriformes	Corvidae	House Crow	*Corvus splendens*	4	4	5	3	16
Passeriformes	Aegithinidae	Common Iora	*Aegithina tiphia*	3	3	0	0	6
Passeriformes	Muscicapidae	Oriental Magpie Robin	*Copsychus Saularis*	1	1	1	1	4
Passeriformes	Locustellidae	Striated Grassbird	*Megalurus palustris*	0	0	0	1	1
Falconiformes	Falconidae	Common Kestrel	*Falco tinnunculus*	0	0	1	0	1
Strigiformes	Strigidae	Asian Barred Owlet	*Glaucidium cuculoides*	3	7	0	3	13
Strigiformes	Strigidae	Spotted Owlet	*Athene brama*	2	5	3	0	10
Coraciiformes	Coraciidae	Indian Roller	*Coracius benghalensis*	2	4	0	0	6
Psittaciformes	Psittaculidae	Red-breasted Parakeet	*Psitacula alexandri*	1	1	0	0	2
Psittaciformes	Psittaculidae	Parakeet	*Psittacula* Spp.	0	1	0	0	1
Gruiformes	Rallidae	White-breasted Waterhen	*Amourornis phoenicurus*	10	10	2	7	29
Columbiformes	Columbidae	Yellow-footed Green Pegion	*Treron phoenicoptera*	1	3	0	0	4
Columbiformes	Columbidae	Spotted Dove	*Stigmatopelia chinensis*	9	7	4	6	26
Columbiformes	Columbidae	Ferral Pegion	*Columbia livia* (*ferral*)	7	7	4	5	23
Uncategorised	Uncategorised	Raptor Spp.	–	4	15	1	6	24
Uncategorised	Uncategorised	Owlet Spp.	–	0	1	1	1	3
Mammals								
Chiroptera	–	Bat Spp.	–	10	17	9	10	46
Rodentia	Sciuridae	Hoary-bellied Squirrel	*Callosciurus pygerythrus*	2	1	1	0	4
Rodentia	Sciuridae	Squirrel Spp.	–	3	3	1	2	9
Rodentia	Muridae	House Mouse	*Mus musculus*	8	13	13	10	44
Rodentia	Muridae	Large Bandicoot Rat	*Bandicoota indica*	10	12	10	6	38
Rodentia	–	Rat Spp.	–	53	64	80	96	293
Eulipotyphla	–	Shrew Spp.	–	8	9	7	6	30
Eulipotyphla	–	Mole Spp.	–	19	13	6	8	46
Primates	Cercopithecidae	Rhesus Macaque	*Macaca mulata*	0	0	1	0	1
Primates	Cercopithecidae	Macaque Spp.	–	0	1	0	1	2
Carnivora	Felidae	Indian Leopard	*Panthera pardus fusca*	0	0	0	1	1
Carnivora	Viverridae	Small Indian Civet	*Viverricula indica*	0	2	1	1	4
Carnivora	Viverridae	Civet Spp.	–	0	0	0	1	1
Uncategorised	Uncategorised	Unidentified	Unidentified	10	47	33	31	121

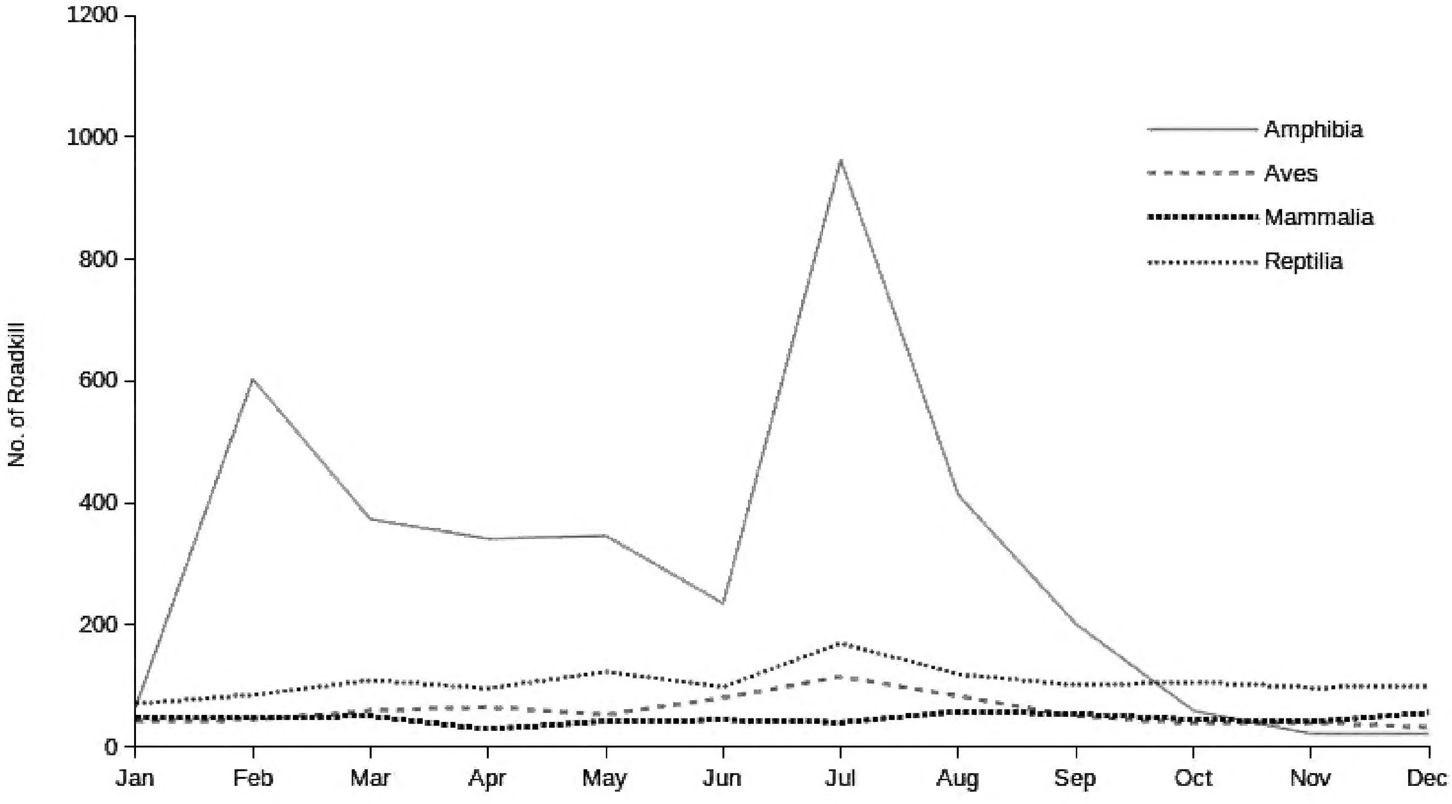

Figure 2. Overall mortality in respective classes.

There were significant differences in the total roadkill numbers by taxonomic groups (χ^2 = 1103.00, $P < 0.01$, df = 3) and multiple comparisons revealed significant differences between amphibians and the other three groups ($P < 0.01$; Table 2), showing amphibians with highest casualties, followed by reptiles, birds and mammals. Of the total casualties recorded, 72.53% (n = 4561) of kills, were found to be old kills and 27.46% (n = 1727) were freshly killed (Mann-Whitney U test, Z = -7.165, $P < 0.01$) wild animals. Roadkill rates were 0.05 carcasses/km for mammals, 0.06/km for birds, 0.13/km for reptiles and 0.39/km for amphibians. Overall mortality rate was found to be 0.65/day/km. However, the percentage rank accumulation pattern of roadkills showed stabilization with the number of survey days (n = 144) for both fresh and old category of road-kills (Figure 3).

Herpetofauna were found to be the most affected group with amphibia being the most affected taxa. The Common Indian toad *Duttaphrynus melanostictus* was found to be highest 54.77%, (n = 1993) among two species and three other taxa of amphibians. Similarly, mortality for Oriental Garden Lizard *Calotes versicolor* was 16.63% (n = 213), followed by Buff Striped Keelback *Amphiesma stolatum* 11.09% (n = 142) and Checkered Keelback *Xenochrophis piscator* and 7.88% (n = 101) respectively among 23 species and nine other taxa of reptiles. Among birds, highest mortality was found in Common Myna *Acridotheres tristis* 23.83% (n = 142) among 22 species and four other taxa of birds, and rat spp. (56.34%, n = 293) among six species and seven other taxa of mammals, were dominant road-kills (Table 1). Some rare road-kill encountered include *Boiga multomaculata*, *Lycodon jara*, *Argyrophis diardii*, *Python bivittatus*, *Gekko gecko*, *Crytodactylus* Spp., among snakes and lizards; *Psittacula krameri*, *Falco tinnunculus*, *Aegithina tiphia*, *Megalurus palustris*, *Lonchura punctulata* among birds

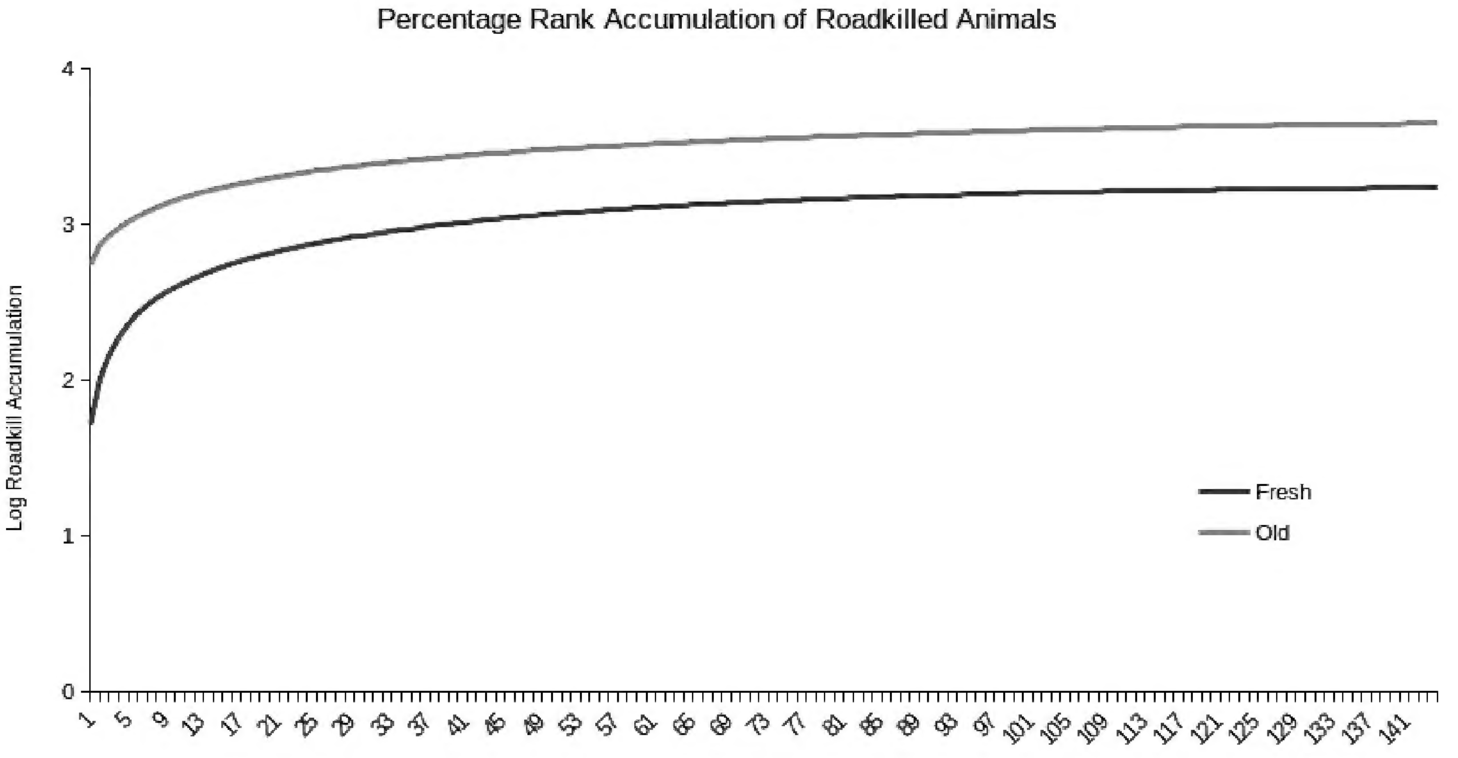

Figure 3. Percentage Rank accumulation of road-killed animals in the study period.

Table 2. Mann-Whitney U Test for total number of roadkills in different seasons and taxonomic group. Win: Winter; PrM: Pre-monsoon; Mon: Monsoon; ReM: Retreating monsoon; Amp: Amphibia; Bir: Birds; Rep: Reptile; Mam: Mammal.

Season	χ^2	Z
	112.30	
Win – PrM	–	3.62**
Win – Mon	–	3.50**
Win – ReM	–	10.82**
PrM – Mon	–	0.13
PrM – ReM	–	8.32**
Mon – ReM	–	8.35**
Taxonomic group	χ^2	**Z**
	1103.00	
Amp – Mam	–	16.37**
Amp – Bir	–	19.24**
Amp – Rep	–	25.90**
Rep – Bir	–	2.65**
Rep – Mam	–	4.93**
Bir – Mam	–	1.98*

‘ ** ’ Significant (P < 0.01); ‘ * ’ Significant (P < 0.05); ‘ ’ Not Significant

and *Panthera pardus*, *Viverricula indica*, *Callosciurus pygerythrus*, *Macaca mullata* were among the mammals.

Among all the road-killed animals found, 96.7% (n = 503) were nocturnal mammals, with species like *Panthera pardus*, *Vivvericula indica*, various unidentified bat, rat mole and shrew species, followed by 14.98% (n = 192) of nocturnal reptiles, belonging to genera *Gekko*, *Boiga*, *Lycodon*, *Bungurus*, and *Trimeresurus* and 4.36% (n = 26) of nocturnal avian species represented by *Athene brama*, *Glaucidium cuculoides* were recorded.

Seasonality of roadkills

Altogether 63.60% (n = 3839) of roadkills occurred during the flooding period: April to September (Pre-monsoon and Monsoon) and 36.40% (n = 2197) of kills occurred in the non-flooding period: October to March (retreating monsoon and winter), with significant differences among them (Kruskal-Wallis, $\chi^2 = 8.56$, $P < 0.01$, df = 1). Thus, we recorded that animal mortality in flooding period was high when compared to mortality in non-flooding period.

This study shows higher mortality in a different season of the year, with maximum kills of 38.37% (n = 2413) in the monsoon season, followed by 25.84% (n = 1625) in winter, 24.84% (n = 1562) in pre-monsoon and 10.94% (n = 688) in retreating monsoon. Thus, the total number of roadkills in each season significantly differs from each other (Kruskal-Wallis test, $\chi^2 = 111.54$, $P < 0.01$, df = 3; Table 2). The Mann Whitney U Test showed significant differences between different seasons ($P < 0.01$) except for pre-monsoon and monsoon (Table 2). The present study also revealed that total amphibian roadkills have significant seasonal variations with the highest mortality in monsoon (2832; $P < 0.01$), followed by pre-monsoon (1689; $P < 0.01$), winter (1661; $P < 0.01$) and retreating monsoon (717; $P < 0.01$), whereas kills in other groups were found to be almost similar throughout the year (Table 2; Figure 4). Moreover, significant differences were found in freshly occurred roadkills in different seasons ($\chi^2 = 47.56$, $P < 0.01$, df = 3) and those found in a decayed state also showed significant differences according to the season ($\chi^2 = 122.41$, $P < 0.01$, df = 3).

The distribution of roadkill records throughout the year was not homogenous, with the highest rates in February, March, July, and August (Table 3). In contrast, November, December, and January showed the lowest roadkill rates. The total casualties in different months revealed significant variations ($\chi^2 = 187.51$, $P < 0.01$, df = 11), with one peak in February-March and a second peak in July-August.

Discussion

The higher incidence of roadkill mortality in the study area is evidence of heavy loss of vertebrate wildlife species in the National highway passing through an important protected area, i.e. KNP of Assam. Similar types of study conducted across the globe also reached comparable findings (Glista et al. 2008; Baskaran and Boominathan 2010; D'Amico et al. 2015). The percentage rank accumulation pattern of roadkill here shows stabilisation with the number of survey days for both fresh and old category of roadkill, thus depicting appropriate survey effort for the concerned study period. However, it is found that only 70 higher roadkill days accounted for 80% of the roadkill statistics in the NH 715 (new) that passes through KNP. This, in turn, signifies the low average number of casualties in most of the survey days (> 70 days), thereby marking the problem to be manageable, if high risk days are identified and proper measures enforced for controlling animal mortality.

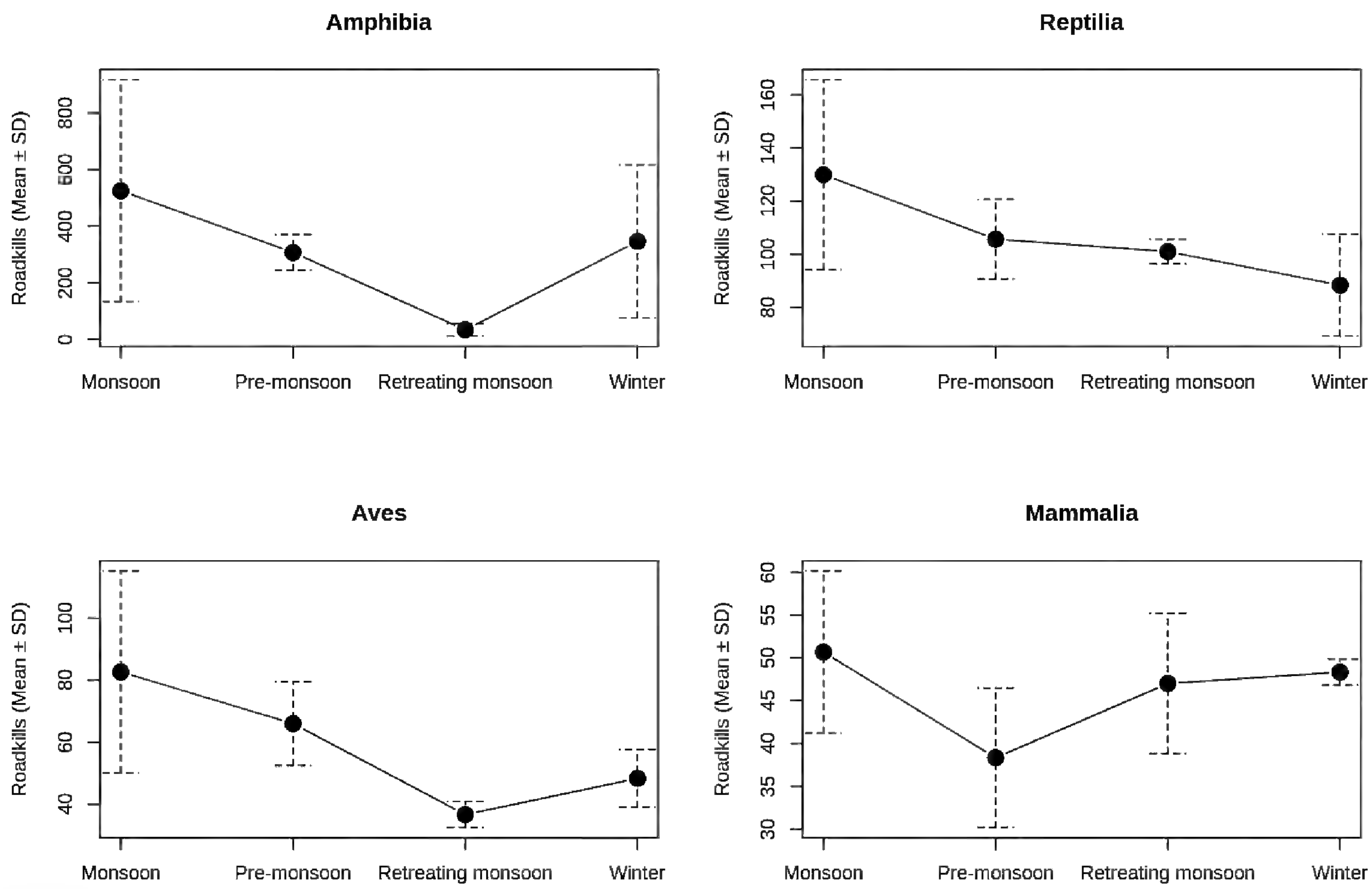

Figure 4. Overall season-wise mean road-kills in different animal groups in the study area.

Table 3. Monthly summary of mortality with percentage kill, mean and standard deviation.

Month	N	Percentage kill (%)	Mean	Standard Deviation
January	217	3.6	1.1	0.41
February	771	12.77	1.9	6.99
March	584	9.68	1.61	1.57
April	515	8.53	1.59	1.6
May	556	9.21	1.43	1.27
June	458	7.59	1.22	0.86
July	1265	20.96	2.7	18.21
August	649	10.75	1.75	2.58
September	396	6.56	1.41	1.32
October	236	3.91	1.08	0.34
November	191	3.16	1.03	0.18
December	198	3.28	1.03	0.16

The present study accounts for the highest number of amphibian roadkills, (60.29%) and thus concurs with the view of Sundar (2004) that amphibians are more vulnerable to collisions with vehicles because they cross roads slowly and are not easily noticeable. Hence drivers tend to disregard them, and this is exacerbated by their activity pattern and population structure (Hels and Buchwald 2001). However, due to lack of existing data on the abundance and ecological structure of amphibia inhabiting the road habitats, in earlier studies in North East India, it hinders us from making any comparative assessment of our work. Hence, we, for the first time are providing quantitative data on roadkill mortalities of amphibia from this region. Also,

our findings are in conjunction with that of Vijayakumar et al. (2001) from Anamalai hills, that *Duttaphrynus melanostictus* are dominant among amphibian roadkills. This could be attributed to their high abundance in this area, since they are cosmopolitan in distribution (Dutta 1997) and are known to be abundant in disturbed habitats (Inger et al. 1984). Amphibians gather near street lampposts and vehicle head lights to feast on insects and also show high human commensalism (Daniels 2005), hence could be more prone to roadkills. This study recorded a high number of amphibian mortality during the wet season, marking a sharp increase with the onset of monsoon (February – March) and during monsoon (July – August), but ending with a tremendous decline in the dry season. This bimodal pattern of roadkill observed corresponds to the seasonality of the climate of this region, since this period corresponds to the rainiest season in the study area with rainfall peaks during these months. This could be linked to their breeding pattern and behaviour, as it drives them to aggregate near water bodies (Hels and Buchwald 2001) and thus augments with the findings of Smith and Dodd (2003), in their roadkill study in Florida, where most amphibian roadkills were related to water levels. Therefore, if traffic intensity continues to increase, the increasing roadkill rates may eventually reduce the population to a level where its reproductive output will be too small to reach the carrying capacities of the breeding pools, which in turn may drive the population to a level where demographic stochastic processes become important for the survival of the population (Hels and Buchwald 2001).

There are plenty of reptile roadkill studies from other parts of the country (Seshadri et al. 2009; Baskaran and Boominathan 2010) but focusing on this part of Northeast India only Das et al. (2007) has reflected the gravity of this problem and provided ample evidence of roadkills. Their study recorded 68 individuals of reptiles of which 89.7% were snakes followed by lizards 10.2%, and *Boiga gokool* was the most highly encountered reptile. Whereas, our study revealed a total of 1281 individual reptiles of which 79.70% were snakes and 20.29% were lizards, with *Calotes versicolor* revealed to be the most affected among lizards and *Amphiesma stolatum* among snakes, hence marking an ultimate increase in the number of lizard kills. There are several factors responsible for such a disparity between the studies. For example, changes in traffic velocity, since the study was conducted more than a decade ago, and differences in sampling period and effort. Being, poikilothermic in nature (Porter 1972), reptiles have been consistently reported to be severely affected by road traffic (Trombulak and Frissell 2000) and the present observations on roadkill from NH-715, supports this. Dodd et al. (1989) and Das et al. (2007) postulated that reptiles are more tempted by roads, in order to maintain their body temperature overnight, as the road surface remain warmer than the nearby areas. Also, the movement of reptiles, particularly snakes, is impeded on road surfaces, and hence increases their risk of mortality (Roe et al. 2006). The current findings of very high numbers of lizard (*Calotes versicolor*) compared to snakes, could be attributed to the higher number of canopy gaps between both sides of the road, thus enhancing their activity near the road. In addition, most lizard kills were observed in locations with high canopy gaps. However, this finding remains in disparity with the findings of Dodd et al. (1989) and Das et al. (2007).

Bernardino and Dalrymphe (1992) found a substantial increase in the number of snake mortalities during the dry season (37% of total kills) as compared to mortalities in the wet season but our study reflects a more or less equal distribution of snake mortality throughout the year. This could be because of the high breeding activity of most of the snakes during the summer and the rainy season (Chittaragi and Hosetti 2014), and mortality during the dry season could have occurred because of increased vehicular influx of visitors to the park, since increase in traffic volume in conjunction with movement rates, makes the animals more prone to roadkill (Chittaragi and Hosetti 2014). Also, unlike mammals, water does not act as a limiting factor for reptile movement during the floods.

Birds are attracted to roads as a location of resource availability, notably food. (Rytwinski and Fahrig 2012). The road attracts predator populations towards particular small mammals and carrion, insects and worms washed out on to roads, and snakes that are attracted to the heat (Erritzoe et al. 2003). Other resources found near or on the roads are grit and salt (Erritzoe et al. 2003), puddles that serve as a water source (Hodson 1962), telephone and power lines that serve as perches (Robertson 1930) and road fencing that offer breeding sites and shelter (Mead 1997). Hence an enormous number of birds fall victims to vehicular collision, while they concentrate on these resources available along roads. A study in Mudumalai Tiger reserve by Bhaskaran and Boominathan (2010) found that birds were least affected by traffic and comprised 7% of the total kills. Also, it was augmented that birds are less susceptible to vehicular hits because of their ability to fly away quickly. However, the present study recorded 9.87% (n = 596) of avian mortality and found them to be highly susceptible to roadkill due to combination of a variety of factors. Birds thus, mostly succumb to ecological traps, since they descend on the road to feed on carcasses of other road killed animals, small insects, grains spread on the road by fringe farmers, grits and small sand particles, specifically by some species (S. S. personal observation) and to prey on amphibians and reptiles available on the paved road. It was also observed that nocturnal birds like owlets were vulnerable to roadkill, colliding frequently with fast-moving vehicles in this area of study because of their low-level flight and predatory behaviour (Boves 2007). Here, at certain areas where there has been higher bird mortality, both the sides of the highway are at a much lower elevation, and birds, when flying from the lowlands, get hit by vehicles while crossing the highway. The fact that birds were more affected during the wet season than the dry season could be because of the increase in herpetofaunal movement on the road, depicting the high availability of prey and also the increase in carcass availability.

This study recorded the mortality of an endangered carnivore, one Indian Leopard *Panthera pardus* and three Small Indian Civet *Viverricula indica*. These figures seem to be very small compared to other taxa, but such loss is intolerable considering their low population density. Several similar studies across India have reported a high roadkill of large cats (Gruisen 1998a; Bhaskaran and Boominathan 2010). Various studies in mammal roadkill in India conducted in many protected areas have also documented the deaths of many species of conservation concern (Rajvanshi et al. 2001). This study

also records the roadkill of a primate Rhesus Macaque *macaca mullata*. Although the mortality rate is lower, the number is still significant. Rhesus macaques were observed crossing the highway almost daily at certain locations, but mostly nearer to human settlements. Although they are very intelligent and highly adaptive primates, they still fall victim to roadkill. Most of the mammal roadkills recorded in this study are nocturnal (Bandicoot Rat, Indian Leopard, Small Indian Civet, House Mouse, and various unidentified Rat and Bat Sp.) species that could have been killed while crossing the roads, as they get blinded by the vehicle's headlights (Bhaskaran and Boominathan 2010). Also rat and mouse mortality seemed to be higher in areas near agricultural patches and at the time of rearing of paddy (S. S. personal observation).

Also, a substantial majority of the animal carcasses, 1.92% (n = 121) remained unidentified and categorised as "uncategorised", since they could only be identified up to order, due to their extreme decomposed state. This, in turn, opens up the scope for further detailed studies regarding more precise identification of roadkills.

Conclusion

In conclusion, it could be said that mortality due to collisions with vehicles has been identified as a major conservation issue, but one that is very challenging to address. Ecologists have been trying to diarize the estimation of road-kills for a long time (Stoner 1925), but their impacts are difficult to quantify and requires systematic studies (Smith and Dodd 2003). However due to a variety of factors like searcher efficiency (Kline and Swann 1998), scavenger bias (Boves 2007) or actual cause of death (Kerlinger and Lein 1988), these figures may remain underestimated. Likewise, the figures can also be over-estimated, considering only carcasses are being studied (Hernandez 1988). Therefore, a more detailed study of the same is vital. . This study is prefatory in nature, and further detailed survey of roadkills in relation to species occupancy, their abundance and behaviour will help in understanding the problem at a broader level. Nevertheless, our work clearly indicates the perilous concerns of this issue, revealing a very high number of annual roadkills.. The major factor contributing to these roadkills is the high speed of the vehicles. Thus, reduction of speed should be managed along with proper mitigation designs for the safe movement and existence of all the animals.

Linear infrastructures are an integral part of our daily system and are a major root of developmental activities. But development must always run in parallel with our naturally functioning ecosystem, since our sustenance depends upon the sustenance of nature. Hence, we need not put a stop to development but rather incorporate proper and eco-friendly designs and innovations in tandem with it, in order to reduce vehicular collisions in intrusions within any protected area. It is thereby, important to quantify the magnitude and the effect of vehicular traffic on faunal groups, which would help conserve them, as various infrastructure projects, including roads and highways, are being planned to cater to the country's growing needs.

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References

Bager A, Rosa CA (2011) Influence of sampling effort on the estimated richness of road killed vertebrate wildlife. Environmental Management 47(5): 851–858. https://doi.org/10.1007/s00267-011-9656-x

Borthakur M (1986) Weather and Climate of North East India. North-Eastern Geographer 18 (1 & 2).

Baskaran N, Boominathan D (2010) Road kill of animals by highway traffic in the tropical forests of Mudumalai Tiger Reserve, southern India. Journal of Threatened Taxa Communication 2(3): 753–759. https://doi.org/10.11609/JoTT.o2101.753-9

Beeby A, Richmond L (1987) Adaptation by an urban population of the snail *Helix aspersa* to a diet contaminated with lead. Environmental Pollution 46(1): 73–82. [Series A] https://doi.org/10.1016/0269-7491(87)90146-1

Bernardino Jr FS, Dalrymphe GH (1992) Seasonal activity and road mortality of the snakes of the Pahayokee wetlands of the Everglades National Park, USA. Biological Conservation 72(2): 71–75. https://doi.org/10.1016/0006-3207(92)90928-G

Boves T (2007) The effects of roadway mortality on Barn Owls in Southern Idaho and a study of ornamentation in North America Barn Owls. Master's Thesis. Boise State University, Idaho, 108 pp.

Carr LW, Fahrig L (2001) Effect of road traffic on two amphibian species of differing vagility. Conservation Biology 15(4): 1071–1078. https://doi.org/10.1046/j.1523-1739.2001.0150041071.x

Chittaragi JB, Hosetti BB (2014) Road kill mortality of snakes (Squamata: Serpentes) in different land cover areas of Semi-Malnad region, Mid Western Ghats, Shimoga, India. Current Biotica 8(1): 57–65.

D'Amico M, Román L, de los Reyes J, Revilla E (2015) Vertebrate road-kill patterns. Biological Conservation 191: 234–242. https://doi.org/10.1016/j.biocon.2015.06.010

Daniels RJR (2005) Amphibians of Peninsular India, University Press, Hyderabad, 268 pp. [+ 46 pls]

Das I (2002) A Photographic Guide to Snakes and other Reptiles of India, New Holand Publication, UK, 1–2.

Das A, Ahmed MF, Lahkar BP, Sharma P (2007) A pre-liminary report of reptilian mortality on road due to vehicular movement near Kaziranga National Park, Assam, India. Zoos' Print Journal 22(7): 2742–2744. https://doi.org/10.11609/JoTT.ZPJ.1541.2742-4

Desai AA, Baskaran N (1998) Ecology of Malabar Giant Squirrel (*Ratufa indica*) in Mudumalai Wildlife Sanctuary, South India. Technical Report Bombay Natural History Society, Bombay 3(7): 1885–1960.
Dodd Jr CK, Enge KM, Stuart JN (1989) Reptiles on highways in north-central Alabama, USA. Journal of Herpetology 23(2): 197–200. https://doi.org/10.2307/1564036
Dutta SK (1997) Amphibians of India and Sri Lanka, Checklist and Bibliography, Bhubaneswar: Odyssey Publ. House, 342 pp.
Erritzoe J, Mazgajski T, Rejt L (2003) Bird casualties on European roads-a review. Acta Ornithologica 38(2): 77–93. https://doi.org/10.3161/068.038.0204
Findlay CS, Houlahan J (1997) Anthropogenic correlates ofspecies richness in southeastern Ontario wetlands. Conservation Biology 11: 1000–1009. https://doi.org/10.1046/j.1523-1739.1997.96144.x
Fulton GR, Smith M, Choi MN, Takahashi S (2008) Road ecology from a road-side assemblage of forest birds in south-western Australia. Ornithological Science 7(1): 47–57. https://doi.org/10.2326/1347-0558(2008)7[47:REFARA]2.0.CO;2
Glista DJ, Devault TL, Dewoody JA (2008) Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 3(1): 77–87.
Grilo C, Molina-Vacas G, Fernández-Aguilar X, Rodriguez-Ruiz J, Ramiro V, Porto-Peter F, Ascensao F, Roman J, Revilla E (2018) Species-specific movement traits and specialization determine the spatial responses of small mammals towards roads. Landscape and Urban Planning 169: 199–207. https://doi.org/10.1016/j.landurbplan.2017.09.014
Grimmett R, Inskipp C, Inskipp T (2011) Birds of the Indian Subcontinent, Second Edition. UK, Oxford University Press, 480 pp.
Gruisen JV (1998a) Rajasthan. Tiger Link 4(1): 10–11.
Haskell DG (2000) Effects of Forest Roads on Macro invertebrate soil fauna of southern Appalachian Mountains. Conservation Biology 14(1): 57–63. https://doi.org/10.1046/j.1523-1739.2000.99232.x
Hels T, Buchwald E (2001) The effect of road kills on amphibian populations. Biological Conservation 99(3): 331–340. https://doi.org/10.1016/S0006-3207(00)00215-9
Hernandez M (1988) Road mortality of the little owl (*Athene noctua*) in Spain. The Journal of Raptor Research 22: 81–84.
Hodson NL (1962) Some notes on the causes of bird road casualties. Bird Study 9(3): 168–173. https://doi.org/10.1080/00063656209476024
Hourdequin M (2000) Ecological effect of roads. Special section. Conservation Biology 14(1): 16–17. https://doi.org/10.1046/j.1523-1739.2000.99358.x
India Brand Equity Foundation (2019) Assam the land of red rivers and blue hills. https://www.ibef.org/download/Assam-September-2019.pdf [accessed 1 May 2020]
Indian Road Industry Report (2020) Road and Infrastructure Industry Analysis. https://www.ibef.org/archives/industry/roads-reports/indian-roads-industry-analysis-january-2020 [accessed 1 May 2020]
Inger RF, Shaffer HB, Koshy M, Bakde R (1984) A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, South India. Journal of the Bombay Natural History Society 81(2): 406–427, 551–570.

Islam M, Saikia PK (2014) A study on the road-kill herpetofauna of Jeypore Reserve Forest, Assam. NeBIO. An International Journal of Environment and Biodiversity 5(1): 78–83.

Jeganathan P, Mudappa D, Kumar MA, Raman TRS (2018) Seasonal variation in wildlife roadkills in plantations and tropical rainforest in the Anamalai Hills, Western Ghats, India. Current Science 114(3): 619–626. https://doi.org/10.18520/cs/v114/i03/619-626

Kerlinger P, Lein MR (1988) Causes of mortality fat condition and weights of wintering Snowy Owls. Journal of Field Ornithology 59: 7–12.

Kline NC, Swann DE (1998) Quantifying wildlife road mortality in Saguaro National Park. In: Evink GL, Garrett P, Zeigler D, Berry J (Eds) Proceedings of the 1998 International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, FL, 23–31.

Langen TA, Kimberly M, Ogden M, Schwarting LL (2009) Predicting hot spots of herpetofauna road mortality along highway networks. The Journal of Wildlife Management 73(1): 104–114. https://doi.org/10.2193/2008-017

Mader HJ (1984) Animal habitat isolation by roads and agricultural fields. Biological Conservation 29(1): 81–96. https://doi.org/10.1016/0006-3207(84)90015-6

Mazumdar K, Gogoi L (2010) Rescue/Release of Blue-capped Rock Thrush *Monticola cinclorhynchus*. Zoos' Print Journal XXV: 21–22.

McCardle LD, Fontenot CL (2016) The influence of thermal biology on road mortality risk in snakes. Journal of Thermal Biology 56: 39–49. https://doi.org/10.1016/j.jtherbio.2015.12.004

Mead C (1997) A pathetic bundle of feathers. British Wildlife 8: 229–231.

Menon V (2014) Indian Mammals a Field Guide. Hachette Book Publishing India Pvt Ltd, 528 pp.

Mumme RL, Schoech SJ, Woolfenden GW, Fitzpatrick JW (2000) Life and death in the fast lane: Demographic consequences of road mortality in the Florida Scrub Jay. Conservation Biology 14(2): 501–512. https://doi.org/10.1046/j.1523-1739.2000.98370.x

Oxley DJ, Fenton MB, Carmody GR (1974) Effects of roads on populations of small mammals. Journal of Applied Ecology 11(1): 51–59. https://doi.org/10.2307/2402004

Porter KR (1972) Herpetology, W.B. Saunders, Co., Philadelphia, 524 pp.

Quinn JF, Hastings A (1987) Extinction in subdivided habitats. Conservation Biology I(3): 198–208. https://doi.org/10.1111/j.1523-1739.1987.tb00033.x

R Core Team (2013) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Vol. 6, No. 3.

Rajvanshi A, Mathur VB, Teleki GC, Mukherjee SK (2001) Roads, Sensitive Habitats and Wildlife: Environmental Guidelines for India and South Asia, Wildlife Institute of India, Dehradun, 215 pp.

Ramp D, Caldwell J, Edwards KA, Warton D, Croft DB (2005) Modelling of wildlife fatality hotspots along the Snowy Mountain Highway in New South Wales, Australia. Biological Conservation 126(4): 474–490. https://doi.org/10.1016/j.biocon.2005.07.001

ROADS – Statistical Year Book India (2018) Statistical Year Book India. http://www.mospi.gov.in/statistical-year-book-india/2018/190 [accessed 1 May 2020]

Robertson JM (1930) Roads and birds. The Condor 32(3): 142–146. https://doi.org/10.2307/1363445

Roe JH, Gibson J, Kingsbury BA (2006) Beyond the wetland border: Estimating the impacts of roads for two species of water snakes. Biological Conservation 130(2): 161–168. https://doi.org/10.1016/j.biocon.2005.12.010

Rosa CA, Bager A (2012) Seasonality and habitat types affect roadkill of neotropical birds. Journal of Environmental Management 97: 1–5. https://doi.org/10.1016/j.jenvman.2011.11.004

Rytwinski T, Fahrig L (2012) Do species life history traits explain population responses to roads? A meta-analysis. Biological Conservation 147(1): 87–98. https://doi.org/10.1016/j.biocon.2011.11.023

Seshadri KS, Yadev A, Gururaja KV (2009) Road kills of amphibians in different land use areas from Sharavathi river basin, central Western Ghats India. Journal of Threatened Taxa 1(11): 549–552. https://doi.org/10.11609/JoTT.o2148.549-52

Smith LL, Dodd CK (2003) Wildlife mortality on highway US 441 across Paynes Prairie, Alachua County, Florida. Florida Scientist 66: 128–140.

Stoner D (1925) The Toll of the Automobile. Science 61(1568): 1568–5657. https://doi.org/10.1126/science.61.1568.56

Sundar GKS (2004) Mortality of herpetofauna, birds and mammals due to vehicular traffic in Etawah District, Utter Pradesh, India. Journal of the Bombay Natural History Society 101(3): 392–398.

Trombulak SC, Frissell CA (2000) Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14(1): 18–30. https://doi.org/10.1046/j.1523-1739.2000.99084.x

Vijayakumar SP, Vasudevan K, Ishwar NM (2001) Herpetofaunal mortality on the roads in the Annamalai Hills, southern Western Ghats. Hamadryad 26(2): 265–272.

Whitaker R, Captain A (2004) Snakes of India: The Field Guide, Draco Books, India, 495 pp.

Supplementary material 1

Figures S1–S5

Authors: Somoyita Sur, Prasanta Kumar Saikia, Malabika Kakati Saikia

Data type: zip archive

Explanation note: Road-killed Amphibians, snakes, lizards, birds, mammals.

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